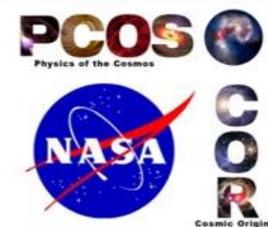


Laser Interferometer Space Antenna

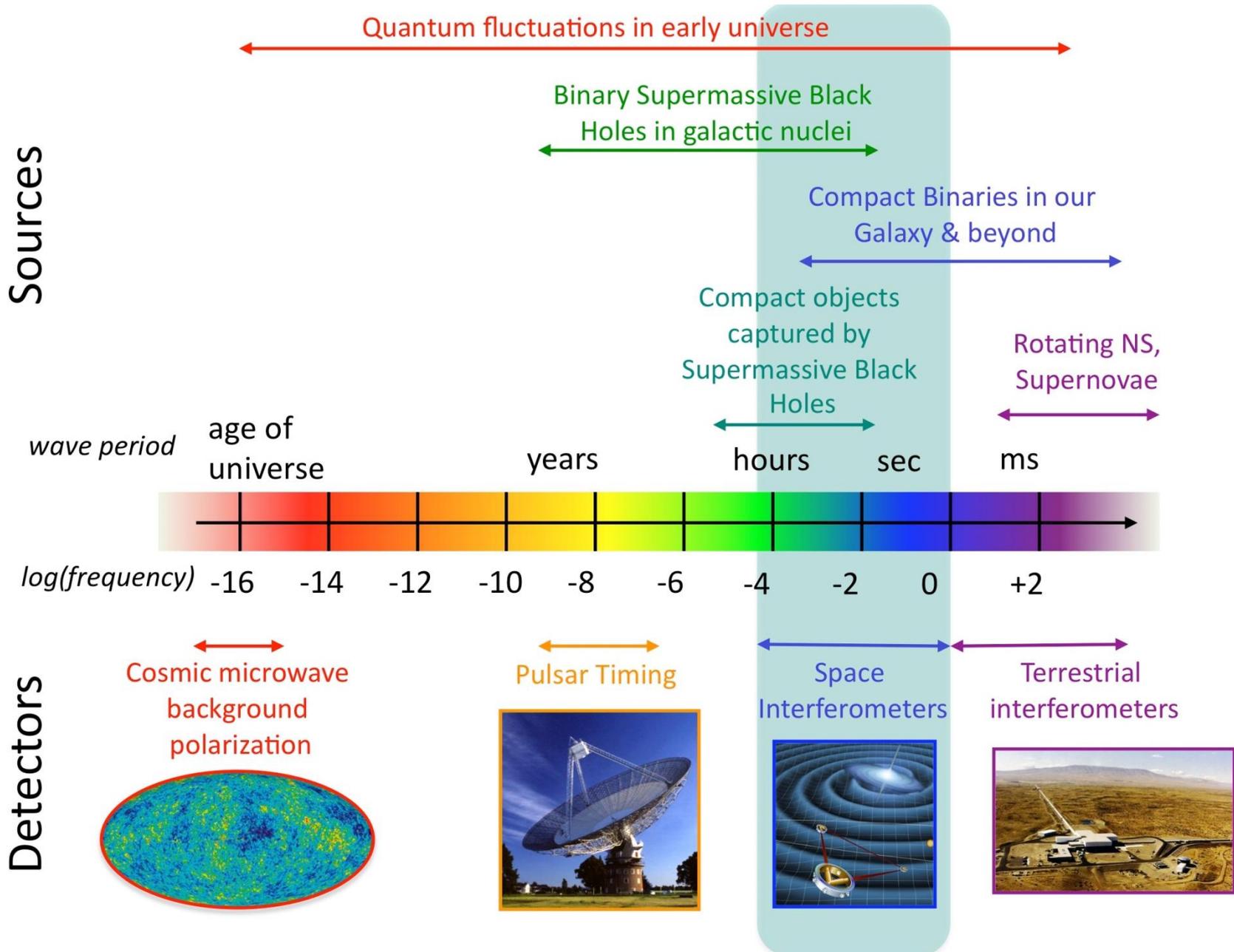
Mission update

John W. Conklin
jwconklin@ufl.edu

Thanks to Ira Thorpe, GSFC



The GW Spectrum

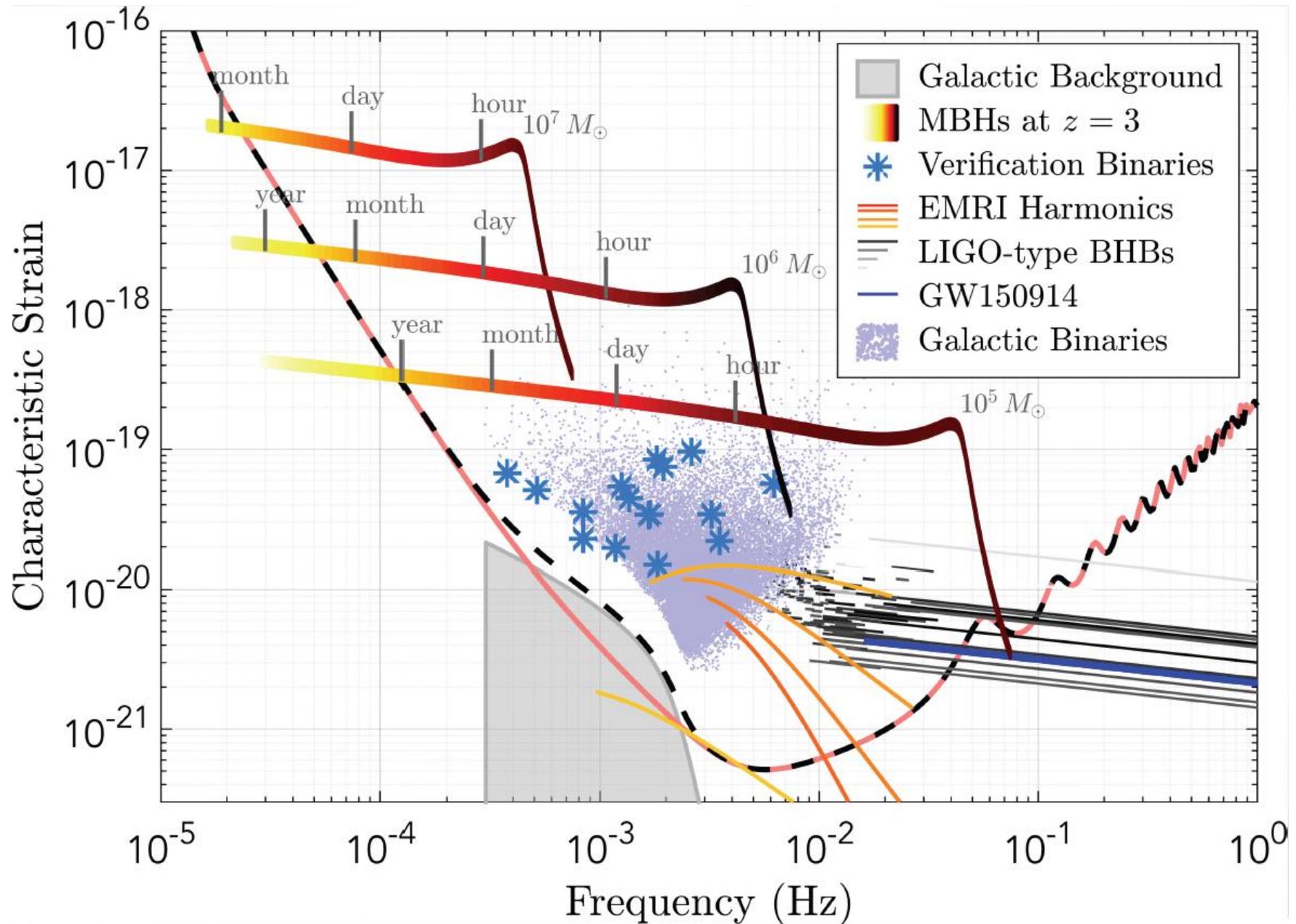


The Laser Interferometer Space Antenna

ESA-led with major NASA involvement
1st space-borne gravitational wave observatory

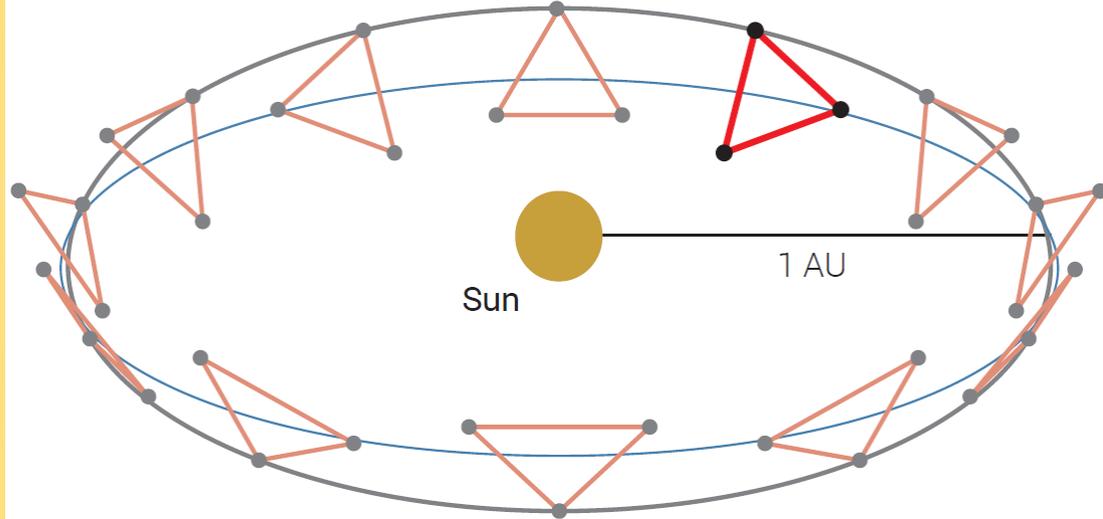
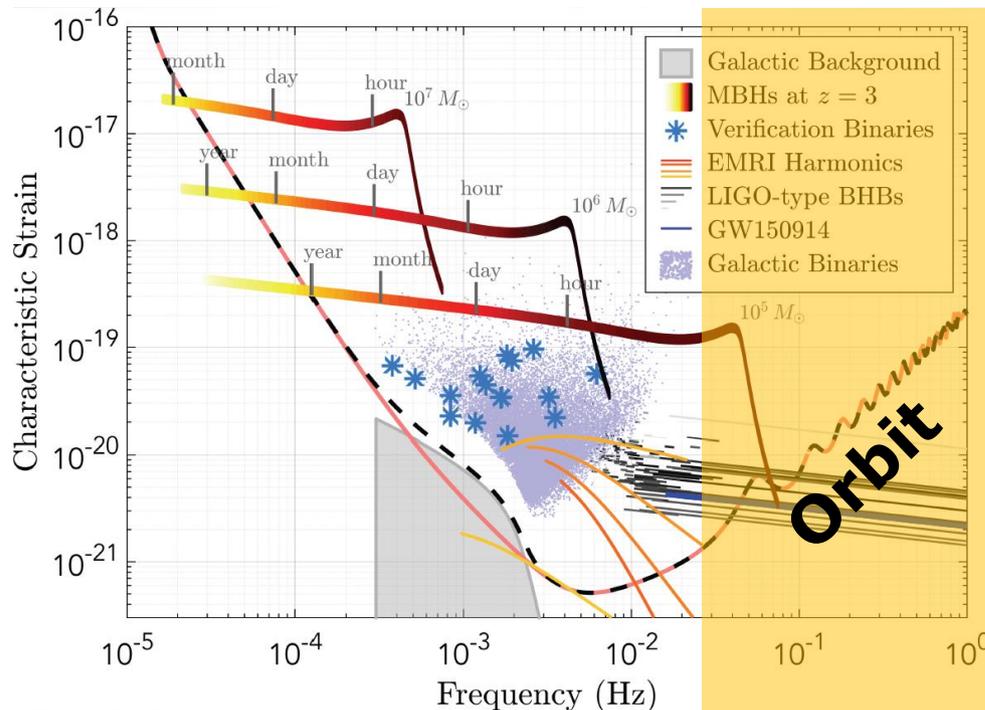
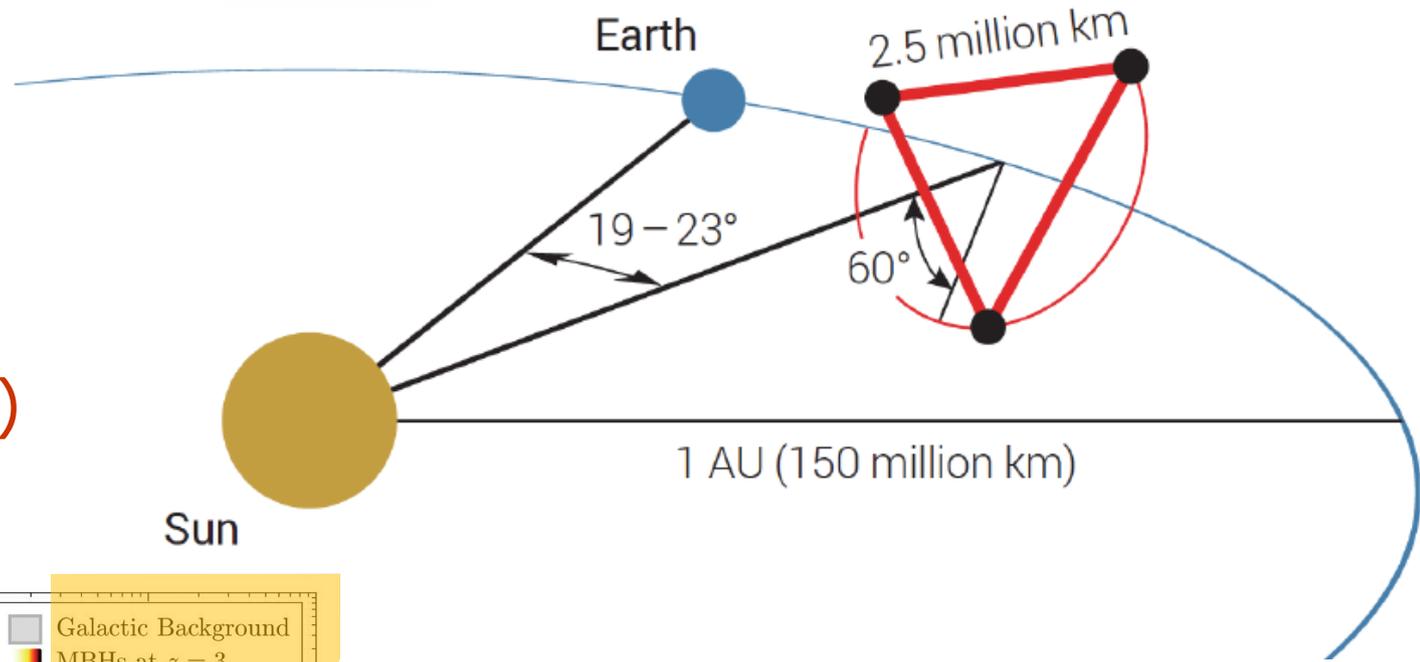
3 drag-free spacecraft
2.5 million km triangle in heliocentric orbit
Launch: early 2030's

LISA Sensitivity Curve

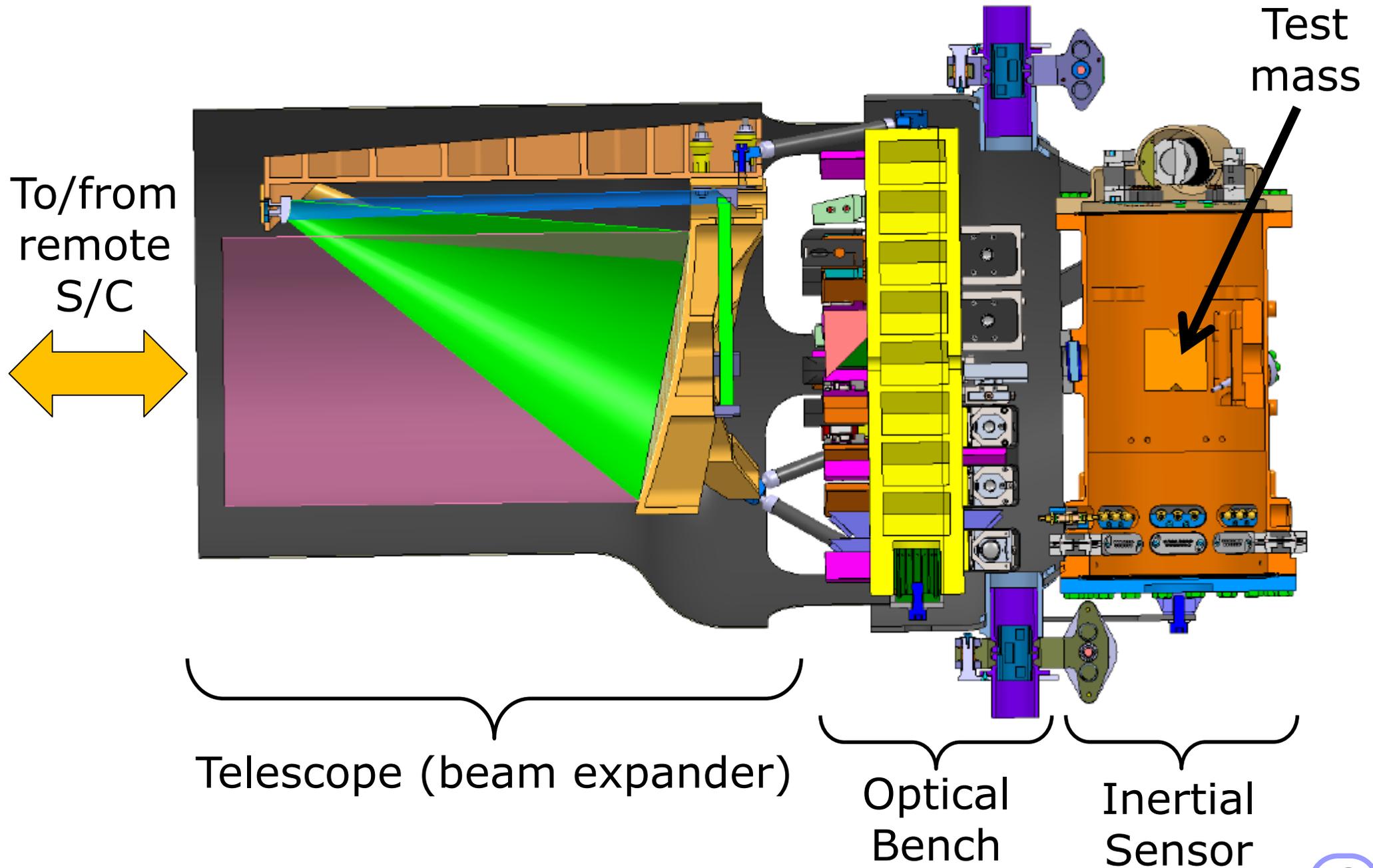


Strain Curve → Orbit

- 4 yr mission
 - 10 yr extension
- 3 arms
(6 one-way links)

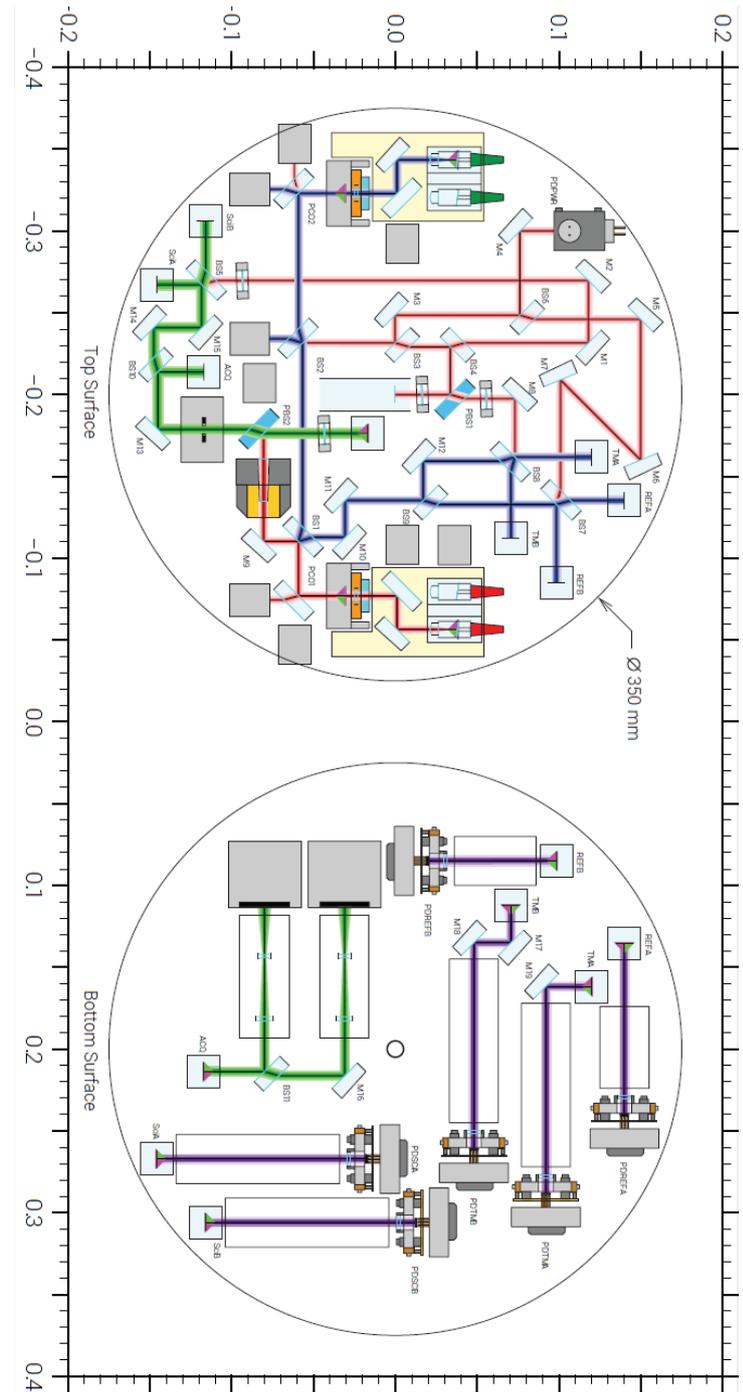
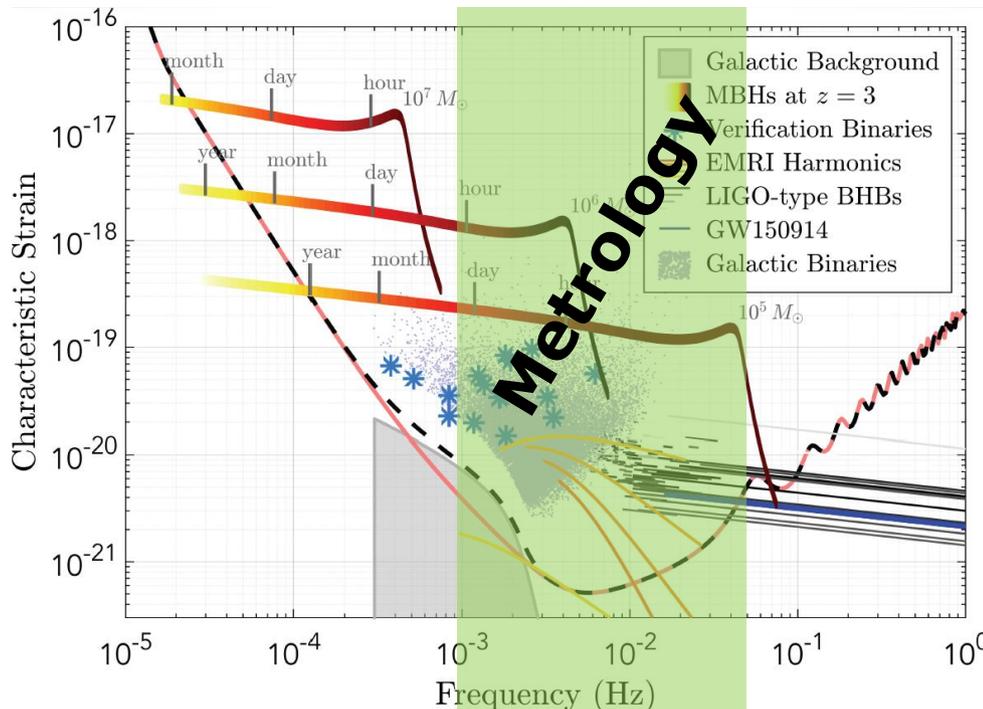


LISA Core Instrument



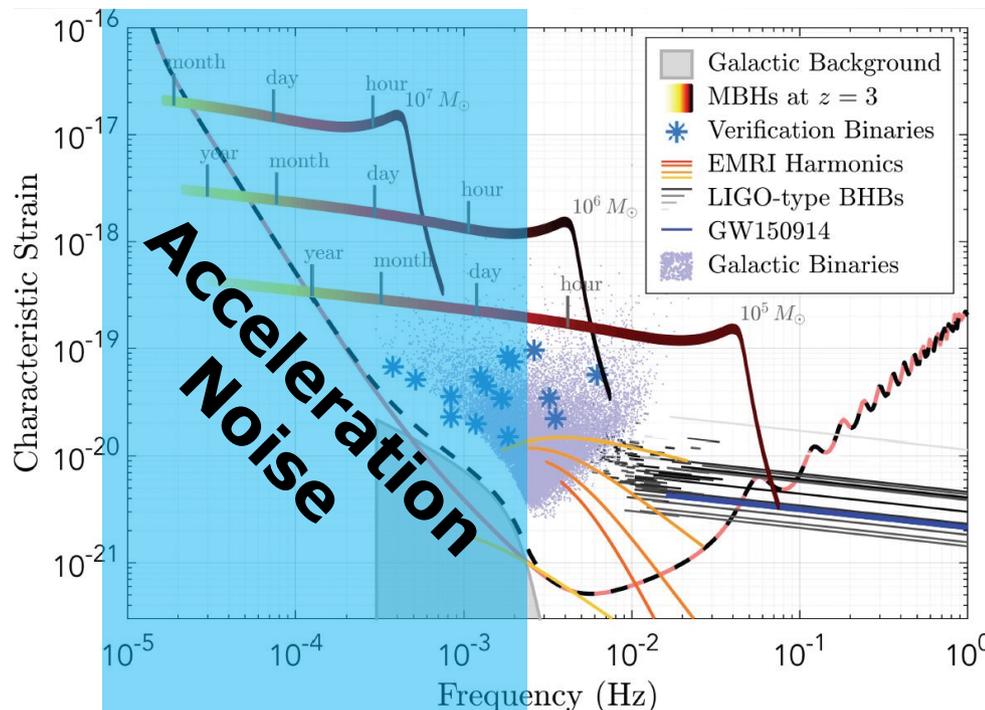
Strain Curve → Metrology

- 10 pm/Hz^{1/2} one-way
 - 2 W, 1064 nm lasers with frequency stabilization
 - Low CTE optical benches with 4 interferometers
 - μ cycle over MHz phasemeter
 - 30 cm telescopes



Strain Curve → Acceleration Noise

- **Disturbance Reduction System**
 - Inertial sensor with test masses, electrode housings, electronics, charge control, caging mechanism
 - Drag-free control using microthrusters
 - Quiet thermal, EM, gravitational environment with monitoring



Top-level LISA Mission Organization

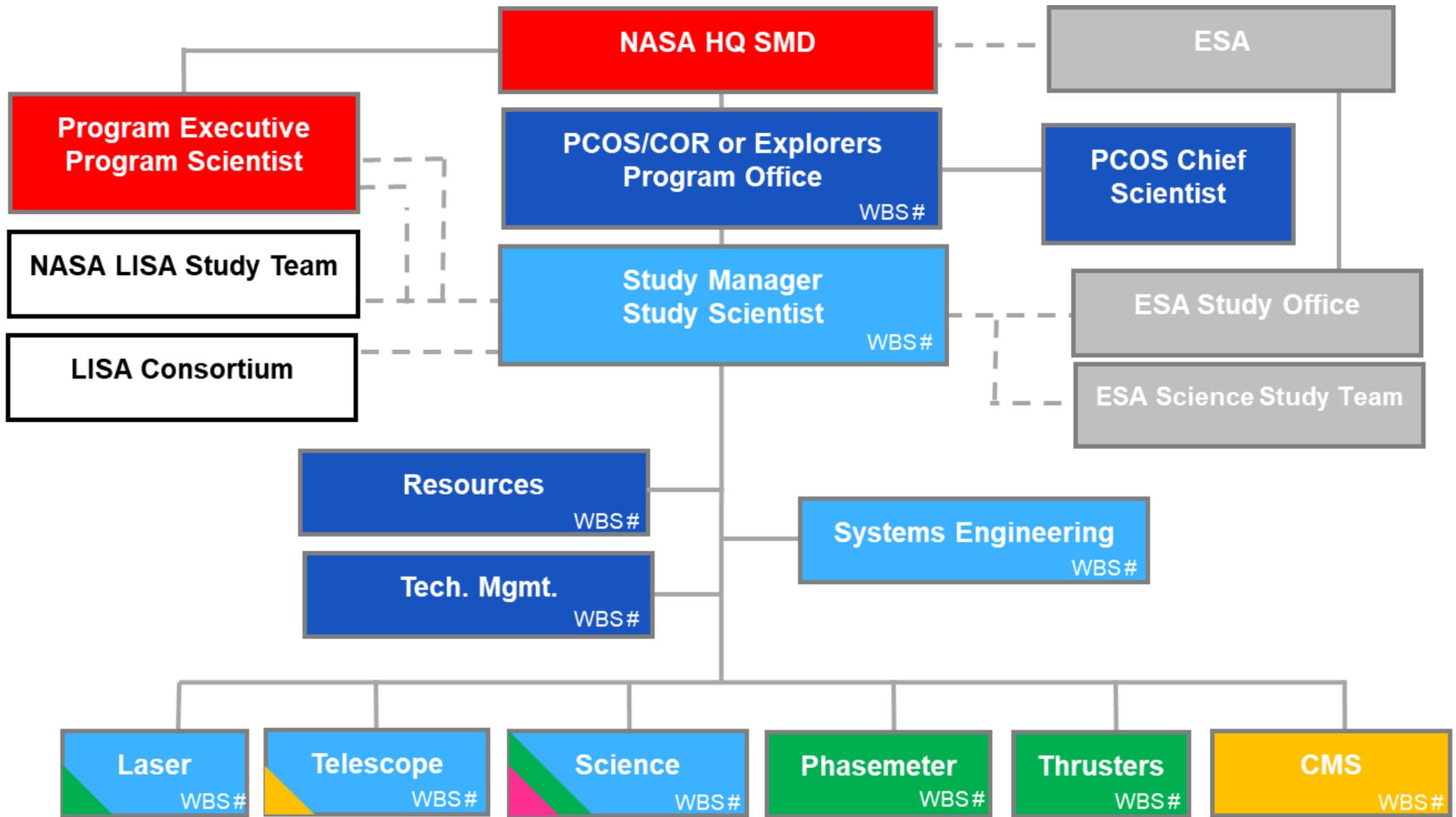
- Mission lead – European Space Agency
- Mission Industrial Prime
 - Competitive in Phase A (now); Down-select before Phase B (2020)
 - Airbus D & S, Germany
 - Thales Alenia Space, Italy
 - Possible NASA Contributions to LISA platform
- Science Instrument
 - LISA Consortium: Instrument lead
 - Airbus D & S: Instrument architect
 - European member state instrument contributions
 - NASA instrument contributions
- Science
 - LISA Consortium consisting of European and U.S. members

NASA LISA Study Office

- “proto-project”
 - Conducts pre-formulation activities w/o formal project structure
 - Will evolve into formal NASA Project Office
- Hosted by Physics of the Cosmos (PCOS) Program
 - Program responsible for science themes including GW
- Executed by NASA field centers, Academia
 - GSFC: management, science, sys. eng; telescope, laser
 - JPL: science, sys. eng. support; interferometry, micropropulsion
 - MSFC: science support
 - UF: CMS, telescope testing



Organization Chart

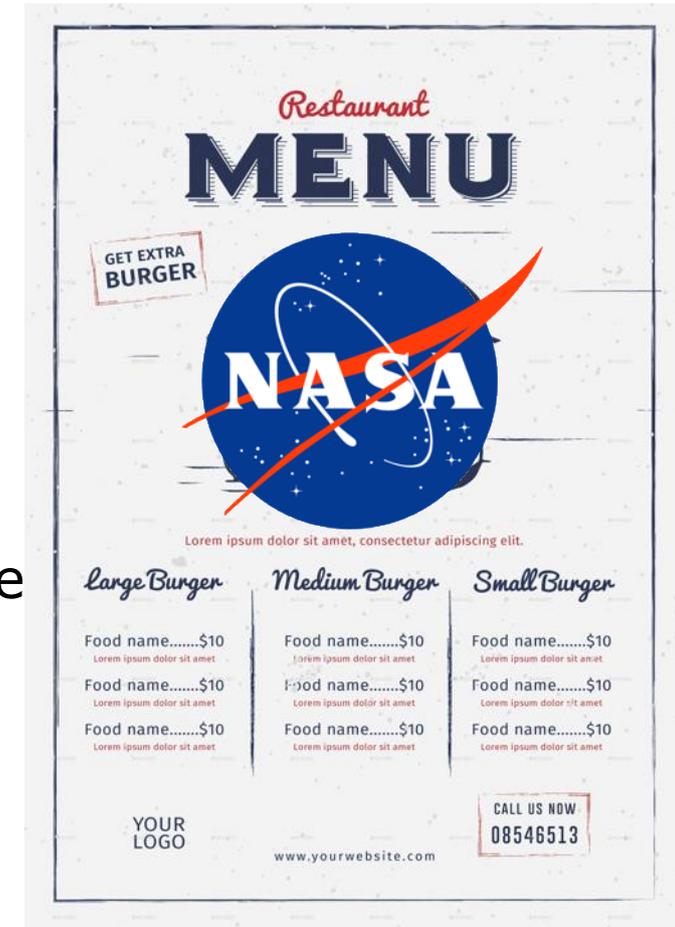


LEGEND

■ NASA HQ	■ ESA	■ PCOS/COR Program Office	■ GSFC	■ JPL	■ UF	■ MSFC
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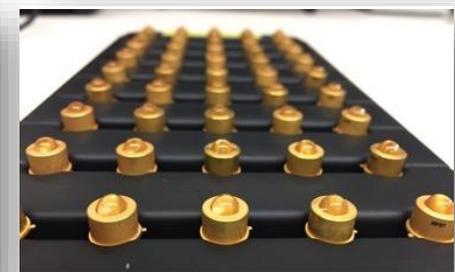
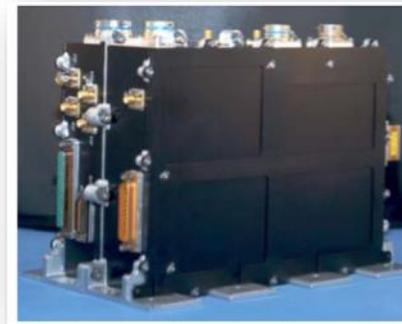
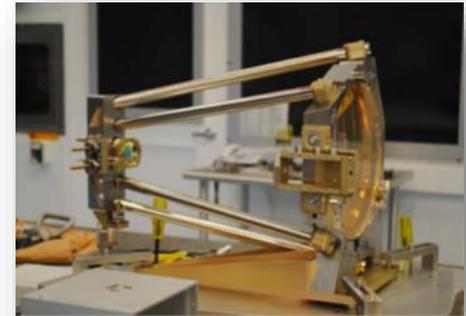
Study Office Near-term Goals

- Develop “menu” of possible NASA contributions
 - Payload systems and subelements (req. tech development)
 - Spacecraft components
 - Ground segment contributions
 - Operations contributions
 - Science support
 - ...
- Assess each contribution
 - Compatibility with partners/ease of interface
 - US interest
 - NASA capabilities
 - Cost
- Work with NASA HQ, ESA, Consortium to consolidate final roles and responsibilities



U.S. Technology Development

- **Goal**
 - Bring a handful of critical technologies to sufficient readiness prior to mission adoption (goal: TRL6 by 2022)
 - Demonstrate key driving requirements, reduce risk
- **Investment strategy**
 - US heritage/expertise
 - insight into the GW instrument
 - known and tractable interfaces
- **Technologies**
 - Stable Laser system (GSFC+JPL)
 - Telescope (GSFC+UF)
 - Phase measurement, interferometry processing (JPL)
 - Micropropulsion (JPL)
 - Charge management (U. Florida)



LISA & Astro2020

- LISA is part of the “program of record”
 - It is an ongoing activity with a baseline cost accounted for in NASA spending projections
- Astro2020 will still comment on LISA
 - From the Statement of task:

*“The study will **assess** whether **NASA’s plans of** WFIRST, Athena, and **LISA** play an appropriate role in the research strategy for the next decade. The study may include findings and **recommendations regarding these plans**, as appropriate, **including substantive changes** to NASA’s plans. Recommendations may include, but are not limited to, actions ranging from **increased investments (upscopes) to reduced investments (descopes) and termination**. It is **not necessary to rank** WFIRST, Athena, and **LISA** among other recommended activities for space”*

How NASA/Community is Preparing

- **Science whitepapers**
 - 11 organized by the NLST
 - Many others relate to LISA
- **Develop Supporting Material**
(not submitted, available as reference, e.g. lisa.nasa.gov)
 - Overall Science Case
 - Technical Readiness
 - Analysis/Theory Readiness
 - LISA for Observers
 - FAQ, observer tool, graphics, etc.
- **Response to queries from Astro2020**
 - Present baseline plan
 - Assessment of NASA's cost, risk, and science benefits
 - Comment on potential upscales

LISA Mission Schedule

- **Currently in Phase A**
 - Competitive “System Prime” phase
 - Mission and instrument formulation
- **Next milestones**
 - Mission Consolidation Review – Summer 2019
 - Mission Formulation Review – Summer 2020 (Prime down-select)
- **Major milestone: Mission Adoption – end of 2022**
 - Mission design is “frozen”
 - Who is doing what is finalized
- **Launch = Mission Adoption + 9.5 years = early 2030’s**
 - Cruise = 2 years
 - Nominal mission = 4 years
 - Extended mission = 10 years

"For Scientists" on lisa.nasa.gov

- Astro2020 WPs
- FAQ
- More coming soon!

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FAQ

Frequently Asked Questions

Click an individual question to see the answer or use these buttons to show/hide ALL answers.

Show All Hide All

- How does LISA differ from LIGO and other ground-based gravitational wave interferometers?
- How mature is LISA's technology?
- How can LISA observe so many sources simultaneously? Won't there be a source confusion problem?
- How does LISA localize sources and how well will it do so?
- LIGO has already found gravitational waves, why do we need LISA?
- How precisely does the distance between the LISA satellites need to be maintained?
- LIGO and other ground-based interferometers are enormously complex, isn't attempting this in space too difficult?
- How are the three LISA spacecraft able to point at one another?
- How long will the LISA mission last?
- What is NASA's role in LISA?
- How can I get involved with LISA?

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DOCUMENTS: Community White Papers

The astronomy and astrophysics decadal survey Astro2020 is a large and influential study run jointly between the Board of Physics and Astronomy and the Space Studies Board of the National Academies. The U.S. scientific community shares information regarding various important astronomy and astrophysics topics with the members of the study team through the submission of White Papers on each topic. For Astro2020, the science-focused white paper deadline was March 11, 2019. Below you can find the white papers submitted by members of the NASA LISA Study Team in support of the science goals that will be addressed by LISA and other space-based gravitational wave observatories.

ASTRO2020 DECADEAL SCIENCE WHITE PAPER: GRAVITATIONAL WAVE SURVEY OF GALACTIC ULTRA COMPACT BINARIES

Principal Author: **Tyson B. Littenberg** / NASA-MSFC

Download Paper

ABSTRACT
Ultra-compact binaries (UCBs) are systems containing compact or degenerate stars with orbital periods less than one hour. Tens of millions of UCBs are predicted to exist within the Galaxy emitting gravitational waves (GWs) at mHz frequencies. Combining GW searches with electromagnetic (EM) surveys like Gaia and LSST will yield a comprehensive, multi-messenger catalog of UCBs in the galaxy. Joint EM and GW observations enable measurements of masses, radii, and orbital dynamics far beyond what can be achieved by independent EM or GW studies. GW-EM surveys of UCBs in the galaxy will yield a trove of unique insights into the nature of white dwarfs, the formation of compact objects, dynamical interactions in binaries, and energetic, accretion-driven phenomena like Type Ia supernovae.

Principal Author: **Tyson B. Littenberg**
Co-Authors: **Katelyn Breivik, Warren R. Brown, Michael Ercoleous, J. J. Hermes.**

ASTRO2020 DECADEAL SCIENCE WHITE PAPER: COSMOLOGY WITH A SPACE-BASED GRAVITATIONAL WAVE OBSERVATORY

Principal Author: **Robert Caldwell** / Dartmouth College

Download Paper

ABSTRACT
There are two big questions cosmologists would like to answer – How does the Universe work, and what is its origin and destiny? A long wavelength gravitational wave detector – with million km interferometer arms, achievable only from space – gives a unique opportunity to address both of these questions. A sensitive, mHz frequency observatory could use the inspiral and merger of massive black hole binaries as standard sirens, extending our ability to characterize the expansion history of the Universe from the onset of dark energy domination out to a redshift $z \sim 23$. A low-frequency detector, furthermore, offers the best chance for discovery of exotic gravitational wave sources, including a primordial stochastic background, that could reveal clues to the origin of our Universe.

Principal Author: **Robert Caldwell**
Co-Authors: **Mustafa Amin, Craig Heggen, Kelly Holley-Bockelmann, Daniel Holz.**

ASTRO2020 DECADEAL SCIENCE WHITE PAPER: THE GRAVITATIONAL WAVE VIEW OF MASSIVE BLACK HOLES

Principal Author: **M. Colpi**

Download Paper

ABSTRACT
Coalescing, massive black-hole (MBH) binaries are the most powerful sources of gravitational waves (GWs) in the Universe, which makes MBH science a prime focus for ongoing and upcoming GW observatories. The Laser Interferometer Space Antenna (LISA) – a gigameter scale spacebased GW observatory – will grant us access to an immense cosmological volume, revealing MBHs merging when the first cosmic structures assembled in the Dark Ages. LISA will unveil the yet unknown origin of the first quasars, and detect the seething population of MBHs of $10^7 - 10^9 M_{\odot}$ forming within protogalactic halos. The Pulsar Timing Array, a galactic scale GW survey, can access the larger MBHs, the Universe, detecting the cosmic GW background from inspiraling MBH binaries of $\sim 10^6 M_{\odot}$. LISA can measure MBH spins and masses with precision far exceeding that from electromagnetic (EM) probes, and together, both GW observatories will provide the first full census of binary MBHs, and their orbital dynamics, across cosmic time. Detecting the loud gravitational signal of these MBH binaries will also trigger alerts for EM counterpart searches, from decades (PTAs) to hours (LISA) prior to the final merger. By witnessing both the GW and EM signals of MBH mergers, precious information will be gathered about the rich and complex environment in the aftermath of a galaxy collision. The unique GW characterization of MBHs will shed light on the deep link between MBHs of $10^6 - 10^9 M_{\odot}$.